The Laboratory's Basin—a Freshwater Ecosystem

Look closely and you may see the wildlife in our aquatic ecosystem...

The basin, constructed as an artificial body of water, has many of the characteristics of a natural freshwater lake system. It holds 12 million gallons of water, ranges in depth from 2 to 15 feet, and has a surface area of 4 acres.

This small freshwater habitat provides a desirable oasis for an interesting community of plants, amphibians, reptiles, mammals, fish, and birds—providing a glimpse of species found in more natural ponds and lakes. As time passes, it will be interesting to watch as the basin evolves into home for additional interesting species.

What is an ecosystem?

An ecosystem is a geographic area that includes all the living organisms (humans, plants, wildlife, microorganisms), their physical surroundings (air, water, soil), and the natural cycles that sustain them. The interconnections among these elements makes it difficult to manage a single resource without affecting the others in the ecosystem.

Interconnections

The basin, through its wildlife and water, is interconnected with the surrounding area. The wildlife that live here need water, yet may also use terrestrial habitats some distance from the basin. Birds, mammals, and amphibians leave the water's vicinity for varying periods of time during their life cycles and may travel long distances. The water itself also travels. When released, the basin's water flows into the Arroyo Las Positas, which flows into various tributaries, and eventually may flow all the way to the San Francisco Bay. These water and wildlife movements connect the basin to different ecosystems throughout the region.

What's for lunch?

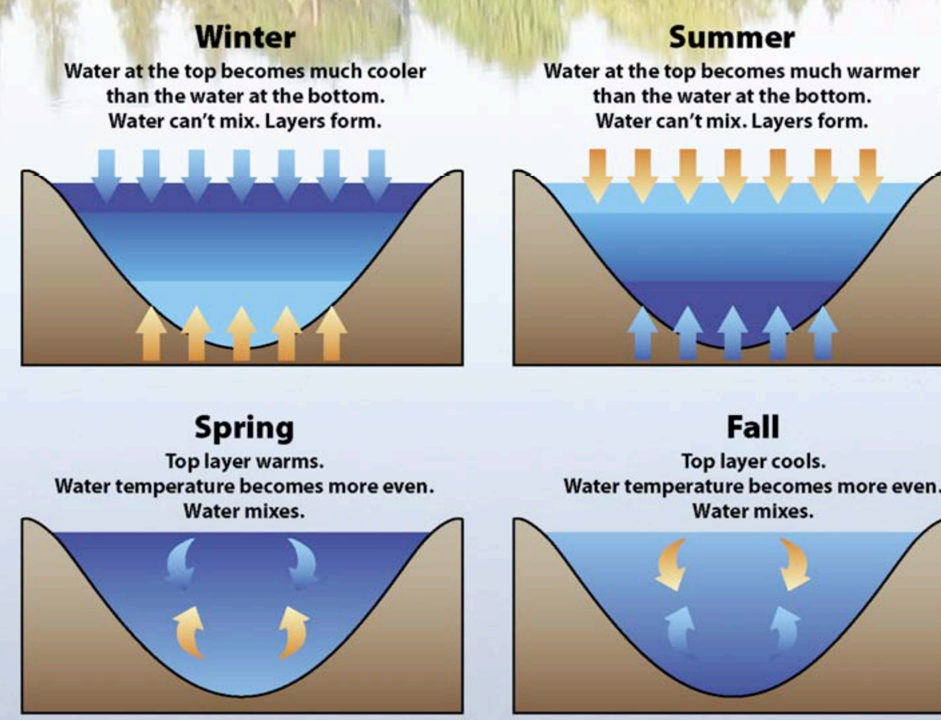
Plants use the sun and inorganic materials (like carbon dioxide) to produce their own food. Generally, the plants feed the herbivores who, in turn, feed the carnivores. In the basin's case, microscopic phytoplankton largely provide the energy base (i.e., food) for higher organisms. Many organisms do not feed exclusively on only plants or only animals, creating a web-effect, rather than a straight food chain between the organisms. The bufflehead duck for instance, feeds on aquatic insects as well as aquatic plant seeds while dragonflies (themselves carnivorous) are food for certain birds and frogs.

One of the most visible embodiments of ecosystem interaction involves the plant and wildlife species. Every living thing needs a food source and every living thing is a potential food source. This creates links from the smallest bacteria to the largest mammal.

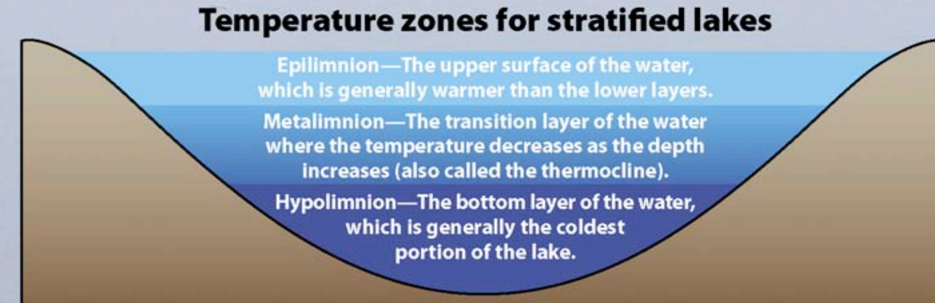
Nature's recycling system

Often overlooked, the realm of the decomposers exists underground. They play an extremely vital role in the health of an ecosystem. The decomposers break down the dead organic matter (detritus material) into its component elements, such as carbon, nitrogen, and phosphorus. Plants use these essential elements and recycle them through the ecosystem where they are utilized by different organisms. All of these organisms eventually become detritus themselves, completing a cycle that repeats over and over again.

Stratification and mixing cycles



Temperature zones for stratified lakes



Abiotic forces

Aquatic factors such as depth, temperature, oxygen levels, light, and turbidity of the water, as well as the grouted rip rap perimeter and bottom sediment depth create niches in the environment for different species to occupy. A niche is defined as the species' habitat and behavior within the ecosystem (i.e., where and how the species lives). The vegetative community, controlled by these abiotic forces, contributes to the habitat variability for the wildlife—for instance the California red-legged frog prefers to hide in the cattails; while others, such as the pied-billed grebe, may prefer the open water.

Basin stratification

The physical structure of the basin creates several different zones of habitation, with different types of organisms living within them. Since it is relatively shallow, the basin may not have an aphotic zone (i.e., water that sunlight cannot penetrate), but it does follow temperature stratification and mixing cycles typical of other lake systems. Stratification is the formation of distinct water layers due to temperature differences between the surface and deeper waters. Coupled with periods of mixing when the water temperature evens throughout the water column, these cycles determine the extent that oxygen and nutrients circulate throughout the water. This, along with the temperature and seasonality of the region, offers our wildlife and plant community some habitat variability.

Freshwater Limited

Three-fourths of the world is covered in water but only 3% is freshwater. The polar ice caps have 75% of that freshwater locked up. Of the freshwater left, a considerable amount is contaminated due largely to industrial, municipal and agricultural pollution. This leaves only about 0.01% of the world's entire water supply available for human use, making every drop of freshwater valuable. The Laboratory's efforts to improve the quality of groundwater and protect surface water quality on site contribute to our clean freshwater supply.

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48. UCRL-POST-213624

Background photo: Megan T. Cook

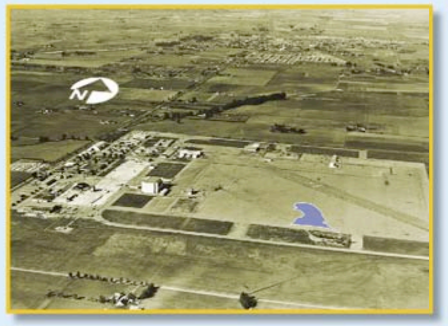
HISTORY OF THE BASIN

The body of water before you is a constructed and engineered aquatic system. The basin was built as a "treatment unit" whose influent (inflow) includes remediated (cleaned) groundwater, storm water, and rainfall. It also provides wildlife habitat and a peaceful refuge for LLNL employees.

The basin receives about 250,000 gallons of treated groundwater every day as a point of discharge for LLNL's groundwater remediation program. This water has been pumped from the contaminated groundwater system and into LLNL treatment facilities for filtering and cleansing, before it's discharged into the basin.

Before the Beginning

In 1942, the area you are looking at was next to an airstrip. With the United States committed to World War II, the U.S. Navy acquired the land (629 acres, now 820 acres) and created the Livermore Naval Air Station where hazardous waste was produced from the solvents and other organic chemicals used for maintaining aircraft.



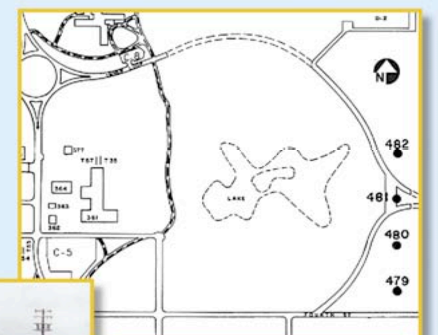
Above left: The blue area shows the future location of the basin. In the 1950s, the site was in its early developing stages and the naval landing strip was still present. Above right: LLNL today.

In 1952, the use of hazardous material and hazardous waste generation continued when the Laboratory began its operations under the ownership of the U.S. Atomic Energy Commission to advance nuclear weapons science and technology.

How the Basin Came to Be

In 1987 LLNL began its program of groundwater remediation under the direction of the Environmental Protection Agency to clean the contaminated groundwater. At that time, the basin was a shallow depression that filled with storm water during the rainy season and dried up during the summer months. It was determined that the remediation efforts were negatively impacted by storm water collecting in this shallow depression because infiltrating water was spreading the already-existing groundwater contamination.

In 1991, this area was excavated to construct the basin and a waterproof liner was installed to prevent infiltration of water into the soil below. In combination with the liner, the shape and components of the basin were engineered and constructed to create a basin that contains both storm water runoff and treated (clean) groundwater.



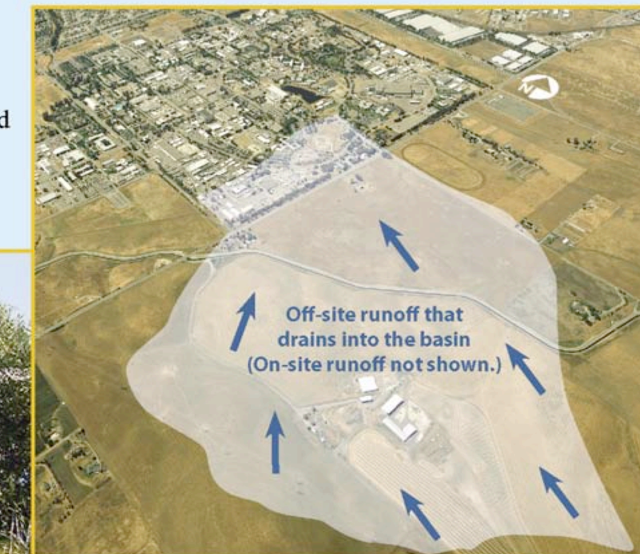
Above: A diagram shows a portion of the plan from 1974 to excavate the area where the basin now stands, prior to any groundwater remediation plans.

Left: Prior to 1991, a shallow depression existed where the basin was constructed. It filled with storm water during the rainy season and dried up during the summer months.

Below: A waterproof liner was installed over the excavated basin.

How the Basin Has Evolved

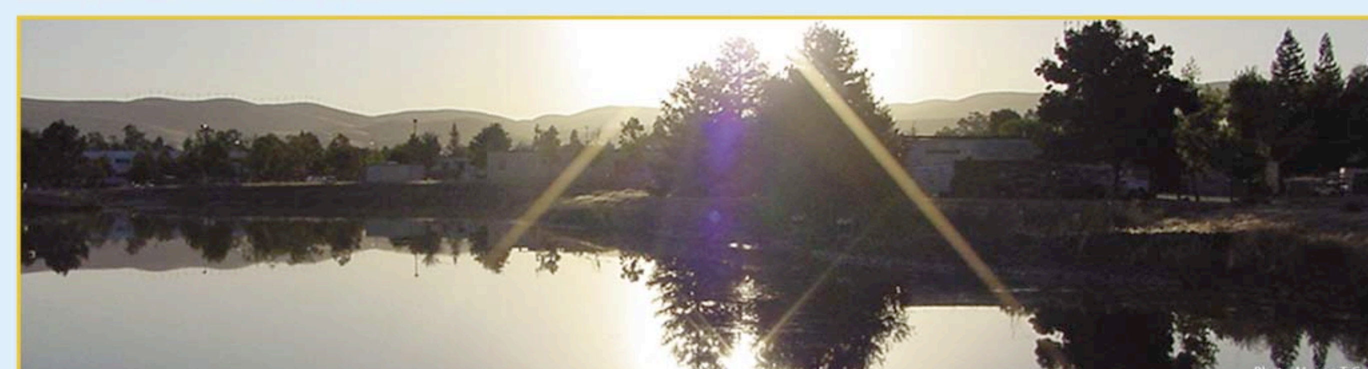
The basin receives storm runoff from approximately a quarter of the LLNL site and 700 to 900 acres of off site land. The basin collects water characteristic of industrial, municipal, and ranchland areas, potentially carrying sediments, nutrients, metals, and other constituents.



Over time the basin has also become a small refuge for wildlife in the arid environment of Livermore. A habitat enhancement pond (shown above, located on the basin's southern side by the Terascale Simulation Facility) was created in 2001 to improve the overall habitat of the basin, particularly for the federally protected California red-legged frog (right).

Above: This is one of the treatment facilities that groundwater goes through before being discharged into the basin.

Below: A summer sun rises over the eastern basin.



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Biodiversity at the Basin

These photos are just a portion of the species that have been known to inhabit, use, or visit the basin at different times of the year.

Benefits of a Man-made Ecosystem

The basin was designed to prevent water from infiltrating into the soil in this area of the Livermore site to protect our groundwater from further contamination and to enhance our ongoing groundwater environmental restoration efforts. It also was designed to temporarily retain and improve the quality of storm water. As a result, the basin naturally became a small freshwater ecosystem that provides habitat and resources for biota.

What is Biodiversity?

Biodiversity is a term that encompasses all living things, the genes they possess, and the ecosystems of which they are a part. It is generally separated into three categories:

- genetic diversity (the variety of genetic material possessed by the individuals in a region);
- species diversity (the variety of all species); and
- ecosystem diversity (the various habitats, biological communities, and ecological processes that exist).

In general, the greater the number of species that exist in a greater number of habitats, the more biodiversity increases.

Biodiversity Matters

Wetlands provide one very tangible example of direct benefits we receive from biodiversity and natural habitats. The natural processes that occur in wetlands help filter and cleanse water we drink and use, which includes the removal of excess nutrients, toxins, metals and other contaminants. Accomplishing these tasks through the use of technology would be complex and expensive, underscoring the immense value of our natural resources as well as the necessity and responsibility to conserve them. Yet California has lost 85–95% of its wetlands since the 1880s. Cleaner water is only one example of the benefits or services we reap from biodiversity of species and habitats. Others include food sources, industrial products, medical models (that help us better understand how the human body functions), new medicines, recreation (e.g., national parks, nature photography), and simply the pleasure of seeing the natural beauty of our earth.

Conserving Biodiversity

Although the basin began as a small "engineered" system, it has naturally evolved into a simple ecosystem, providing habitat for a diversity of migratory and resident wildlife. In fact, the basin provides sanctuary for the federally threatened California red-legged frog. While this basin fulfills its technical objectives related to LLNL groundwater and storm water, it provides a glimpse of the importance of biodiversity in our environment.

Please take this opportunity to enjoy the surroundings and to protect our biodiversity by not releasing anything into the basin (including plants, fish, and frogs).

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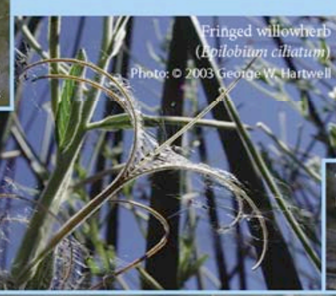
Flame skimmer (*Libellula saturata*) Photo: Megan T. Cook


Common green darner (*Anax junius*) Photo: Tom Young


Muskrat (*Ondatra zibethicus*) Dr. Lloyd Glenn Ingles © 1999 California Academy of Sciences


California Red-legged frog (*Rana aurora draytonii*) Photo: Michael G. van Hattem


Fringed willowherb (*Epilobium ciliatum*) Photo: © 2003 George W. Hartwell


Tule (*Schoenoplectus acutus var. occidentalis*) Photo: © 2003 George W. Hartwell


Western fence lizard (*Sceloporus occidentalis*) Photo: Michael G. van Hattem


Western toad (*Bufo boreas*) Photo: Michael G. van Hattem


Pacific treefrog (*Hyla regilla*) Photo: Michael G. van Hattem


Bullfrog (*Rana catesbeiana*) Photo: Michael G. van Hattem


Black-tailed jackrabbit (*Lepus californicus*) Photo: © 2004 Tom Greer


Broadleaf cattail (*Typha latifolia*) Photo: © 2004 Steve Matson


Tarantula wasp (*Pepsis ssp.*) Photo: Michael G. van Hattem


Gray fox (*Urocyon cinereoargenteus*) Photo: Jim Woollett


Bewick's wren (*Thryomanes bewickii*) Photo: © 2003 Bonterra Consulting


House finch (*Carpodacus mexicanus*) © 2000 Rick Cameron


Yellow-rumped warbler (*Dendroica coronata*) © 2002 Rick Cameron


Red-winged blackbird (*Agelaius phoeniceus*) Photo: Michael G. van Hattem


Killdeer (*Charadrius vociferus*) © 2001 Rick Cameron


American robin (*Turdus migratorius*) © 2001 Rick Cameron

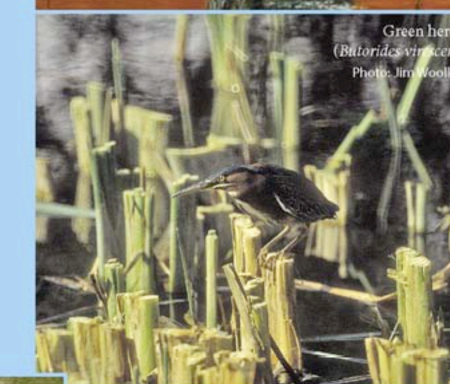

Belted kingfisher (*Ceryle alcyon*) © 2001 Rick Cameron


Pied-billed grebe (*Podilymbus podiceps*) © 2004 Tom Greer


Mallard (*Anas platyrhynchos*) © Rick Cameron


Snowy egret (*Egretta thula*) Photo: Michael G. van Hattem


Great blue heron (*Ardea herodias*) © 2001 Rick Cameron


Green heron (*Butorides virescens*) Photo: Jim Woollett

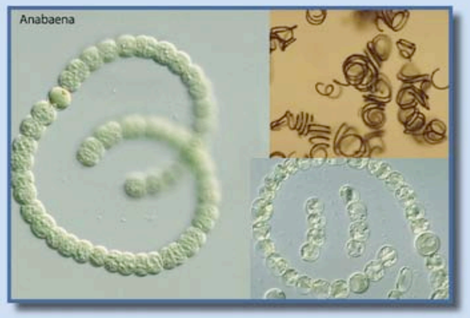

American coot (*Fulica americana*) © 2001 Rick Cameron

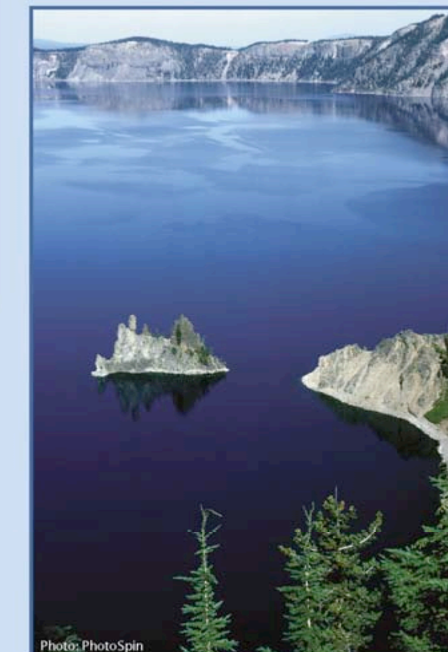

Canada goose (*Branta canadensis*) © 2001 Rick Cameron

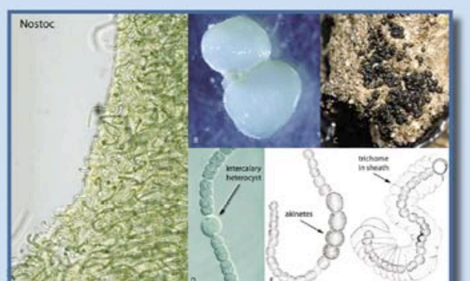

Bufflehead (*Bucephala albeola*) © 2001 Rick Cameron

Algal Blooms—When Single-celled Plants Add Up

Photo: PhotoSpin



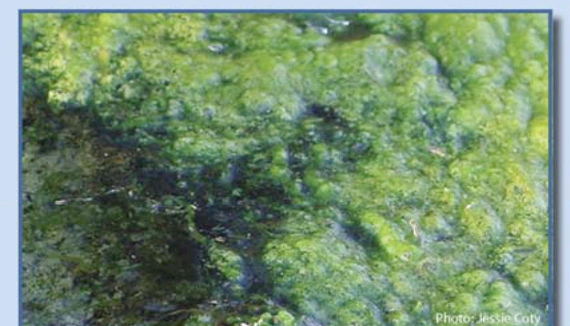




Photos: Entwisle et al. (1997); Drawing: S. Skinner, © Royal Botanic Gardens & Domain Trust, www.rbgsyd.nsw.gov.au

These single cells pictured at left can combine to form huge masses of algae.

Algae masses distinctly change the appearance of the basin (right).



Compare the deep blue water of Crater Lake at right with the close-up at left of some of the algae that periodically covers the surface of the basin.

When the water is green, an algal bloom has formed in the basin...

Algae play a key role in an aquatic system, often without garnering much notice, given their (typically) microscopic size. Freshwater algae (or phytoplankton) vary in shape and color, yet they remain an important basic food source for small aquatic wildlife. Despite their simplicity and relative small size, single-celled plants support a healthy ecosystem and make their presence count!

Yet, when these phytoplankton multiply rapidly and extensively under favorable conditions for their growth, dense aggregations of algae form at the water's surface, resulting in floating, green formations called algal blooms. Dissolved oxygen initially increases, a byproduct of this lush growth, and supports other basin biota. Yet, this thick layer of algae eventually may block the sunlight that once penetrated deep into the water and sustained submerged larger plants. The larger plants subsequently die-off and dissolved oxygen is used for decomposition of this dead organic matter. Later in the season, as the algal formations also decompose, large amounts of dissolved oxygen are similarly removed—further impacting wildlife that need this oxygen to survive. A delicate balance exists in which the algae are numerous enough to serve as a basic food source yet not overly abundant and an impediment to healthy water quality and biota (plants and animals).

Summertime Green

Factors that encourage the rapid growth of algae include temperature, sunlight, pH, and availability of nutrients (especially phosphates and nitrates). During summer, the combination of warmer temperatures, lots of sunshine, lack of rain, and excess nutrients may result in overstimulating the growth of algae, coloring the water a summertime green. This process is called eutrophication and is the opposite of an oligatrophic lake, where the water is cold, clear, and with minimal nutrients and plant growth (for example, Lake Tahoe).

Prevention of algal blooms is key to a healthy, relatively young ecosystem. Some of the basin's water comes from the agricultural and ranchlands around LLNL; this water likely carries excess nutrients. And the hot, dry, and very sunny conditions that typify this area much of the year cannot be changed, adding to favorable conditions for a bloom to occur. Yet, LLNL takes steps to minimize other factors that lie within our control. For example, fertilizers are used sparingly and applied carefully to minimize any runoff into LLNL waterways. Also, the small pond on the opposite side of the inner circle loop is designed to settle out sediments before the water reaches the basin (sediments carry nutrients). To ensure minimal nutrients, the groundwater that LLNL pumps up and cleans is monitored before discharging it into the basin.

Wintertime Blues

With the change of seasons, the scorching heat of summer subsides, sunlight diminishes, and rain falls more often. Algae respond to these less than favorable conditions by dying off, resulting in clearer and bluer water (above right) during winter. The green water (above left), may remain during the early fall season, despite the algal aggregations no longer floating on the surface, as the decomposing algae become submerged yet still color the water.

Eutrophication: A Naturally Slow Process

Eutrophication is a natural process by which lakes gradually age and become more productive. However, natural eutrophication usually takes thousands of years to progress. Humans have greatly accelerated this time frame by polluting the water with excessive nutrients, resulting in anthropogenic eutrophication, which is not a natural nor a healthy process for aquatic ecosystems. This water pollution is primarily caused by runoff or erosion from agricultural fields, urban lawns, and golf courses that have been fertilized.

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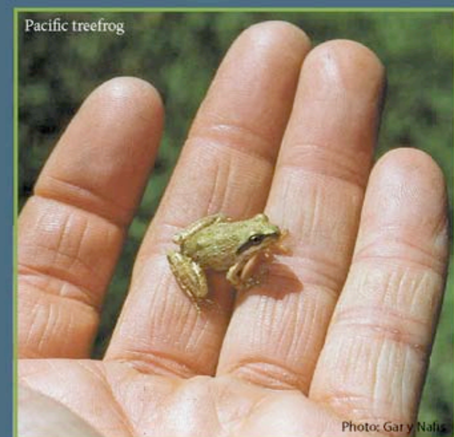
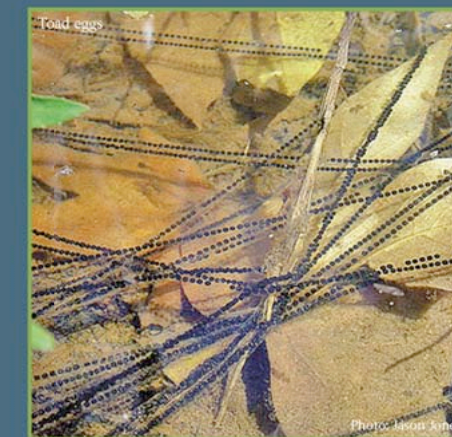
Treefrogs and Toads: Warts Apart


Treefrog eggs
Photo: Gary Nafis


Pacific treefrog
Photo: Gary Nafis

There are several species of amphibians that live in the basin and its vicinity as well as within Arroyo Las Positas and Arroyo Seco, two waterways that traverse portions of the site. This includes the Pacific treefrog and the Western toad, two amphibian species that are not endangered or threatened, but are both native to this area and highly impacted by the invasion of the non-native bullfrog. Treefrogs produce egg masses (left), toads release single-egg-thick strings (right). Both of these species are tiny after they metamorphose from tadpole to frog and emerge from the water. They're only as big as a thumbnail!


Toad eggs
Photo: Jason Jones


Western toad
Photo: Gary Nafis

Pacific Treefrog (*Hyla regilla*)


Photo: Gary Nafis


Photo: Gary Nafis

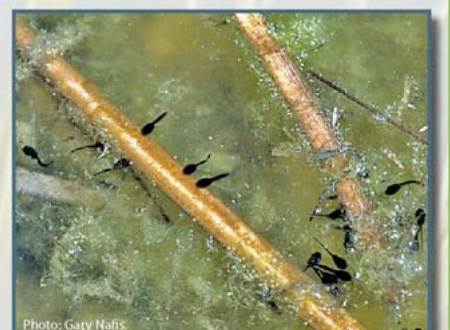


Photo: Gary Nafis

The Pacific treefrog's coloration is extremely variable; it has the unique ability to change its color depending upon the moisture and temperature levels that are present. Shades range from vivid lime green to brown, but each frog has a dark band running across its eye toward its underbelly, which looks like a mask. Despite its name, the Pacific treefrog lives mostly on the ground. Pacific treefrogs are small, growing up to only 5.1 centimeters long (2 inches). This amphibian has relatively smooth skin, unmarked by the "warts" characteristic of toads.

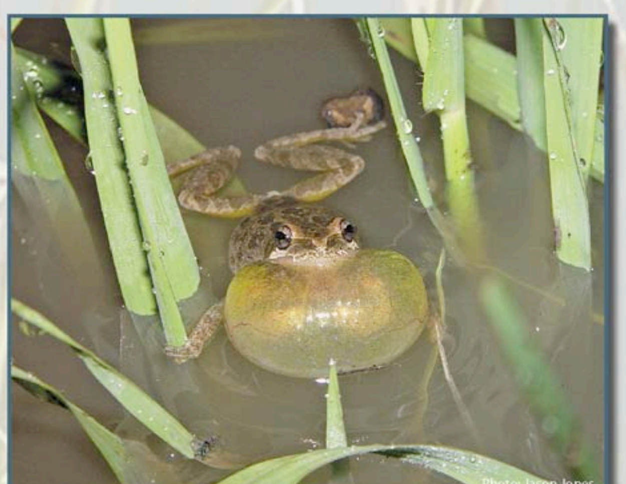


Photo: Jason Jones


Photo: Gary Nafis

Pacific treefrogs, like most amphibians, are considered an "indicator species" because of their extreme sensitivity to changes in the environment and water quality—a built in warning system for scientists to monitor the ecosystem.

The Pacific treefrog has the most common call heard on the Pacific coast. Its vocal sac expands its throat to look like a round balloon. The "ribbit" sound so often used in movies is actually the sound of the Pacific treefrog calling for a mate during its breeding season (Nov–July). Listen closely at night for their symphonic melodies.

Western Toad (*Bufo boreas*)


Photo: Gary Nafis


Photo: Gary Nafis

The Western toad is a common, native species that occupies a wide variety of habitats (from the desert to the mountains) in and around various types of water bodies.

Every adult Western toad has a white or cream-colored stripe running down the center of its back. Their skin is generally a greenish, gray, or dusky color with warts that are often rust-hued and on dark blotches. These toads range in size from approximately 6 to 12 centimeters (2.4 to 4.7 inches). Like other true toads, Western toads are terrestrial and only need a body of water to breed.

These toads breed in shallow, slow moving areas of water. Strands of black "pearl like" eggs that are several feet long are deposited either on the basin bottom or wrapped around objects in the basin like branches (see photo at top right). The tadpoles are easily seen in the basin. They are slow swimmers and congregate together in large schools with uniformly dark and round bodies in the warmest and most shallow areas of the basin. By the end of summer, these tadpoles metamorphize into toadlets and leave the water for land. Toadlets take about three years to mature into adults with a life span of up to ten years.

If you ever pick up one of these toads, be careful—*that warm liquid on your hand is not water!* It's a defense mechanism to keep you (or any other predators) from eating it. If it's an adult, you may hear it vocalize while in your hand with a soft series of chick-like peeps.

Instead of hopping on land like other frogs and toads normally do, adult Western toads prefer to walk. In addition to the "*warm water*" threat response, a toad can secrete a bitter white poison from the parotid glands behind its eyes (see photo above).


Photo: Michael G. van Hattem

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BATTLE OF THE FROGS

Native versus Invasive Species (CALIFORNIA RED-LEGGED FROG versus BULLFROG)

Efforts to conserve biodiversity include protecting native species from non-native (exotic) species. Species are considered non-native when they inhabit areas outside of their natural range and have the ability to reproduce and disperse widely. Competition inevitably results between species when they vie for the same limited resources (i.e., territory, food, cover). Exotic species are often able to out-compete or predate upon native species, an effect that can be synergistic when other environmental stresses are also present (e.g., land development, habitat fragmentation, increased UV radiation, or contamination). Native species may be specifically adapted to their natural environment and may not adapt quickly enough to an altered or disturbed environment. This imbalance can give non-native species an advantage and may critically affect native species, potentially leading to a need for state or federal protection (i.e., the Endangered Species Act) to prevent further endangerment and extinction.

This native versus non-native species battle displayed here in the basin occurs across the globe, in diverse settings and with different species.

In the early part of the twentieth century, California red-legged frogs were in high demand as a desired food item for the growing human population of San Francisco. As they rapidly declined, bullfrogs were brought from the east coast to replace them as a food commodity. This greatly intensified the negative impact on the California red-legged frog, for its predators then included both humans and bullfrogs.

This competitive and detrimental relationship between the California red-legged frog and the bullfrog still exists at the basin today. The California red-legged frog has already been extirpated from 70% of its former range in the state and faces possible extinction if not actively protected where it still exists.

Can you figure out the sex of this bullfrog? (See Bullfrog Facts for help.)

California red-legged frog (*Rana aurora draytonii*)

Status: Federally Threatened and a State Species of Special Concern

The California red-legged frog is the largest native frog of the western United States, its length ranging from 4 to 13 centimeters (1.6 to 5.1 inches). Its abdomen and hind legs are generally red, with distinct dark leg bands. On its back are small black specks with large, irregularly shaped splotches on a reddish, gray, brown or olive-colored background. A whitish jaw stripe is usually obvious. One of the best ways to identify this frog is by its two prominently raised ridges running down its back (called dorsolateral folds).

California Red-legged Frog Facts

- Before wetlands dry out in the summer, these frogs disperse into upland habitats, seeking refuge in burrows, riparian areas, or other wetlands. California red-legged frogs have been documented moving up to two miles in only a few days.
- California red-legged frogs reach sexual maturity after 3 to 4 years, and they can live up to 8 to 10 years.
- An important part of their diet at the basin consists of aquatic dragonfly larvae (known as nymphs).
- Adult California red-legged frogs are mostly nocturnal.
- A female frog breeds only once a season, laying 2,000–5,000 eggs.
- The California red-legged frog inspired Mark Twain's classic tale of The Celebrated Jumping Frog of Calaveras County.

The Benefits of Saving One Frog

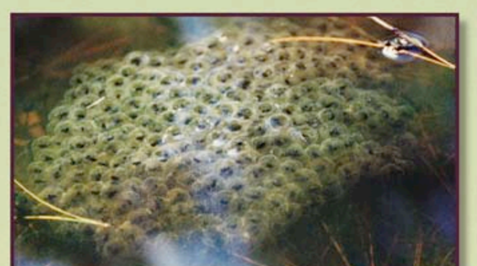
There is a delicate balance in nature, and the basin is a microcosm of how biodiversity benefits us all. The basin's ecological balance offers an opportunity for us to reflect on how an imbalance in this small pond simulates larger imbalances globally.

Each small habitat or preserve is a representative sample of the many similar ecosystems across the state and the nation. Natural systems provide the resources and services we require to sustain our quality of life—and maintaining this is our responsibility as members of this delicate ecosystem and environment.

The Pacific treefrog (*Hyla regilla*), Western toad (*Bufo boreas*), and California red-legged frog are all species that are part of our basin and need protection from the bullfrog.

Photo: Megan T. Cook

The California red-legged frog (above) and the bullfrog (right) both sit and wait for prey to pass by them before they attack.



Bullfrog egg masses (above right) can be enormous, composed of up to 20,000 eggs, dwarfing the California red-legged frog egg masses (above left), which only contain up to 5,000 eggs. Less than 1% of the red-legged frog eggs will make it to adulthood.

This immature 2-year-old bullfrog ate 10 native Pacific treefrogs!

Bullfrog (*Rana catesbeiana*)

Status: Invasive Non-native Species

The bullfrog—the largest frog in North America with its size ranging from 9 to 20 centimeters (3.5 to 7.9 inches)—can be five times bigger than the California red-legged frog. Its coloration is usually a shade of green, but it can also range from browns to dark grays. The tympanum (the external eardrum located directly behind the eye) is very conspicuous.

Bullfrog Facts

- If the tympanum is larger than the eye, the frog is male; if the tympanum is roughly the same size as the eye, the frog is female.
- These frogs reach sexual maturity after 4 to 5 years and live up to 7 to 9 years.
- Female bullfrogs can breed twice in a season, laying up to 20,000 eggs each time.
- The bullfrog's diet usually consists of snakes, small frogs, and crustaceans. The bullfrog can be cannibalistic at times and has also been reported eating bats.
- When startled, a bullfrog often makes a squawking noise as it jumps back into the water.

LLNL wildlife biologists have taken various measures in an attempt to remove the bullfrog from the basin and other areas on site. Efforts have included:

- Installing a mesh screen over the basin's outflow culvert to prevent bullfrog tadpoles and its other life stages from traveling between the basin and Arroyo Las Positas
- Manually removing adult bullfrogs and eggs
- Draining the basin and manually removing bullfrog tadpoles.

Although these actions provide positive steps towards protecting the California red-legged frog, invasive species are very tenacious and difficult to eradicate. As a result, the need to undertake additional measures for bullfrog management is required and will be for years to come.

Help us protect the California red-legged frog by not placing any wildlife or plant species into the basin—be proactive in conserving and balancing our environment.

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48. UCRL-POST-213624

Except as noted, all photos by Michael G. van Hattem

The Muskrat: An Underwater Specialist

Ondatra zibethicus

Fragile beginnings

The muskrat is an altricial species—young are born unable to fend for themselves. Born blind, naked, and helpless, its eyes open after two weeks and it is weaned from its mother after four weeks. A mother may attack a newly weaned young to drive it away before she gives birth to a new litter—muskrats are highly territorial and aggressive toward one another. A fairly prolific breeder, a female muskrat can produce up to four litters a year with 4–6 young each.

Heavy eater

The muskrat's lips close behind its incisors so that it can chew on stems and roots underwater without getting water in its mouth. The ability to chew underwater comes in very handy as the muskrat makes its way through its watery world, eating mostly aquatic plants as well as crustaceans, frogs, and other small vertebrates. A muskrat eats the equivalent of one-third its weight every day!

Olfactory signals

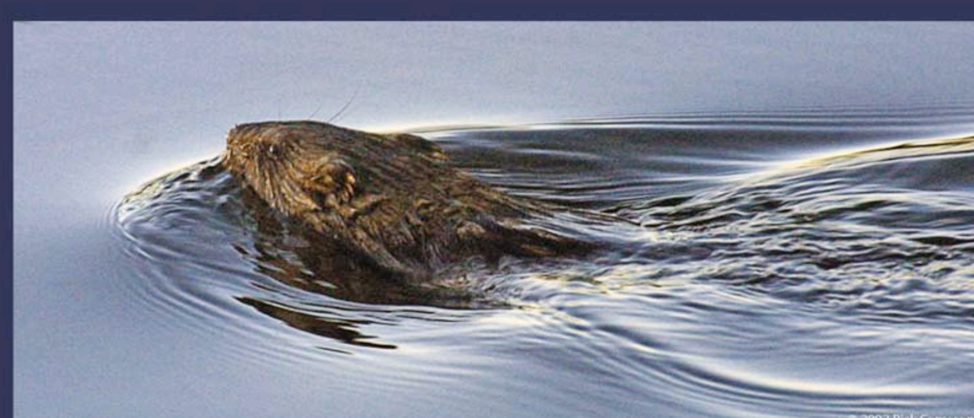
To communicate, muskrats produce a special secretion from their glands called musk. This scent also serves as a warning to intruders.

If you look closely...

You may find a den-type structure made from cattails by this member of the rodent family. It is unknown whether any muskrats have permanently lived in the basin, but they are known to use it from time-to-time so be on the lookout for a furry mammal out for a swim!

Efficient swimmer

This aquatic mammal utilizes several special adaptations for an aquatic lifestyle. The muskrat has partially webbed hind feet, a flat tail for paddling, and the ability to stay under water up to 17 minutes. Its fur is very dense, which traps air underneath to give the muskrat insulation and buoyancy.



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Background photo: PhotoSpin

Dragonflies: Messengers of Summer and Heralds of the Sun

—H. Lons, Poet and Zoologist

Photo: PhotoSpin

The basin is home to several beautiful dragonfly species. Dragonflies are especially interesting insects with delicate wings and brilliant colors. Watch closely as these intricately designed insects dip to the water's surface and dart through the edge vegetation.

Note: Dragonflies and damselflies are commonly and collectively referred to as *dragonflies*.

Flame skinner (*Libellula saturata*)

Photo: Megan T. Cook

Familiar bluet (*Enallagma civile*)

Photo: Ray Bruun

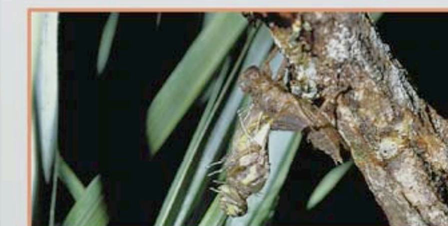
The most common dragonfly and damselfly seen at the basin

Striped meadowhawk, female (*Sympetrum pallipes*)

Photo: Megan T. Cook

Widow skimmer (*Libellula luctuosa*)

Photo sequence: James L. Lasswell, Texas A&M University

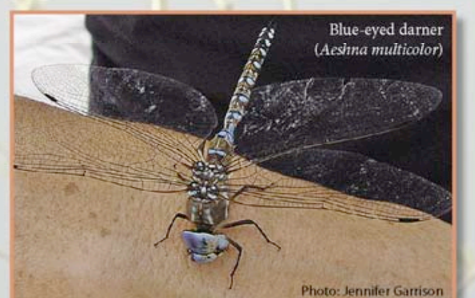


Black saddlebags (*Tramea lacerata*)

Photo: Alex Lorenzini – www.BlueEyeView.com

Familiar bluet (*Enallagma civile*)

Photo: Mike Rubin



Blue-eyed darner (*Aeshna multicolor*)

Photo: Jennifer Garrison

Tule blue damselfly (*Enallagma carunculatum*)

Photo: Ray Bruun

Dragonfly nymph

Photo: ucmp.berkeley.edu

Damselfly nymph

Photo: ucmp.berkeley.edu

Common green darner, male (*Anax junius*)

Photo: Tom Young

Aquatic fliers

Although adult dragonflies are aerial, they are classified as aquatic insects. Only their mature, adult stage is terrestrial. Immature dragonflies are called nymphs and they develop for a few months to four years in freshwater environments. Nymphs and adults are exclusively carnivorous. The nymphs eat a variety of aquatic insects and even tadpoles and small fish, while dragonflies dine on mosquitoes to butterflies as a large part of their adult diet. Some dragonflies hunt for their prey while others prefer to sit and wait for prey to pass by. Dragonflies in turn, comprise a very important part of the diet of the amphibians at the basin, most notably of the California red-legged frog.

Mating embrace

These two damselflies (above) are mating. The male has his abdomen tip clasping the female behind the head, who has brought the tip of her abdomen underneath and up to the male to retrieve sperm.

Speedy bugs

Dragonflies can reach incredible flight speeds. Estimates are between 15–22 mph. The average person walks 3 mph.

Dragonfly or Damselfly?

Dragonflies are very closely related to damselflies (both in order Odonata) and they share similar characteristics. The easiest way to tell them apart is to look at how they hold their wings at rest. Dragonflies keep their wings out (above left), while the damselflies fold theirs up (above right). Damselflies are also smaller and more delicate than dragonflies. Dragonflies and damselflies begin their lives as nymphs, living underwater for a year or more. On the bottom left is a dragonfly nymph, whose abdomen ends in three short spines and whose gills are held internally. On the bottom right is a damselfly nymph, recognizable by the three feathery gills extending from the tip of its abdomen. The nymphs are not as brightly colored as the adults, but are well camouflaged predators who ambush their prey.

Migrating insects?

Migration is not normally associated with insects, but some dragonfly species (such as the common green darner above) are known to migrate alone or in masses that can contain millions of individuals. Research of this phenomenon has been increasing in recent years, but there is still much to discover.

Out and about

Adult dragonflies announce the beginning to a new sunny season, emerging from their nymph stage adorned in their vibrant hues during the warm temperatures of spring and summer. In the sequence above, the thorax of a larva splits shortly after it exits the water. Within an hour, the adult begins to metamorphose. Fully emerged, the dragonfly's wings and abdomen expand to full size within 4 or 5 hours. Enjoy the bright splashes of color these insects add to the basin!

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Background photo: Megan T. Cook